Exposure Study On UV-induced Degradation Of White Diffusers

Catherine C. Cooksey[1], Benjamin K. Tsai[1*], David W. Allen[1], Christopher C. White[2], Eric Byrd[2], and Deborah Jacobs[2]

[1.] National Institute of Standards and Technology, Sensor Science Division, Gaithersburg, MD, USA.
[2.] National Institute of Standards and Technology, Materials and Structural Systems Division, Gaithersburg, MD, USA.
* Corresponding author: benjamin.tsai@nist.gov

UV imaging has seen recent growth in applications and increased product availability. These applications include astronomy, photolithography, material inspection, forensics, chemical detection, and skin reflectance. Increased demand in the UV will likely drive an increase in demand for reliable optical references that are stable in this spectral region.

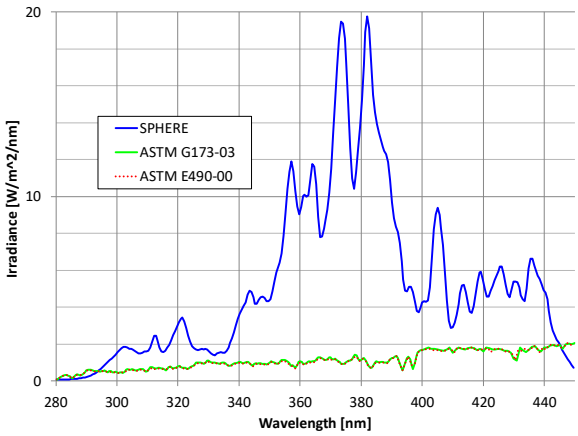
One factor that could potentially change the characteristics of calibration standards is ultraviolet (UV) induced degradation. For example, in onboard space calibrations, UV exposure from the sun can result in errors in the calibration of space-flight instruments.

The objective of this study is to assess UV exposure effects on materials commonly used as reflectance standards using UV irradiation generated by the NIST facility, Simulated Photodegradation via High Energy Radiation Exposure or SPHERE [1]. The facility consists of a 2 m integrating sphere that provides a source of intense ultraviolet radiation from the 290 nm to 400 nm. It uniformly illuminates samples with high level of irradiance that mimics terrestrial UV solar exposure at an accelerated rate. Beginning in 2014, sintered polytetrafluoroethylene (PTFE) and ceramic samples were exposed to UV irradiation generated by SPHERE for a total exposure time equivalent to 4.35 solar years. For each sample, the directional-hemispherical reflectance factor (DHRF), bidirectional reflectance distribution function (BRDF), and fluorescence were measured before UV exposure began and after it ended a year later. The DHRF of each sample was also measured every 12 weeks during the exposure period.

Results show significant decrease (maximum of approximately 6% at 350 nm) in the reflectance properties of the ceramic samples, while the reflectance properties of the PTFE samples were unchanged for most wavelengths. This decrease observed for ceramic samples occurred within the first 12 weeks of UV exposure and remained stable for the remaining 36 weeks of exposure. For wavelengths greater than 350 nm, neither the control nor exposed PTFE samples showed any change in their reflectance properties. However, the control and exposed PTFE samples exhibit opposite trends for wavelengths less than 350 nm. The reason for these changes is not obvious and could be related to storage conditions or uncertainty of measurement for wavelengths less than 350 nm. An investigation of all samples before and after UV exposure found no discernible changes in fluorescence. Additionally, visual inspection of the samples revealed no change in the appearance of the surfaces.

Previous studies have investigated changes to the reflectance properties induced by UV exposure for a variety of commonly used diffuse reflectance materials. Exposure levels ranged from low, such as those experienced during typical laboratory and measurement conditions, to high, such as those experienced by onboard space-flight instruments. The results presented here represented an intermediate scenario, namely, long-term, terrestrial UV solar exposure.

References:
[1] J Chin, E Byrd, N Embree, J Garver, B Dickens, T Finn, and J Martin, Rev. Sci. Instrum., 75, (2004) p. 4951.
[2] B Tsai, C Cooksey, D Allen, C White, E Byrd, and D Jacobs, Applied Optics, 58, (2019) p. 1215.



	Integrated Irradiance 275 nm to 450 nm
SPHERE	901.7 W/m^2
ASTM E490	190.3 W/m^2
ASTM G173	189.8 W/m^2

Figure 1. Comparison of SPHERE output and ASTM solar spectra (left). Integrated irradiance (right).

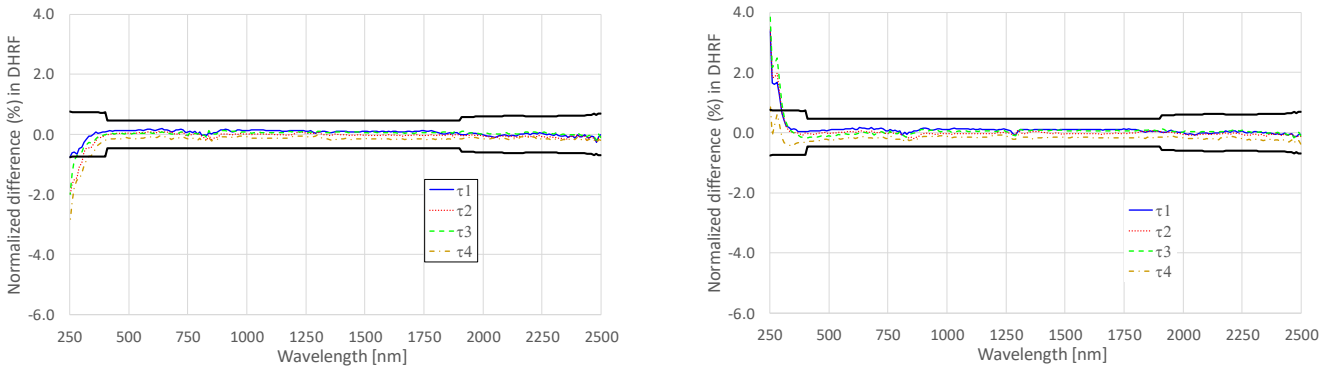


Figure 2. Normalized difference (%) in DHRF for control (left) and UV exposed (right) PTFE samples as a function of wavelength at each characterization time during the exposure period.

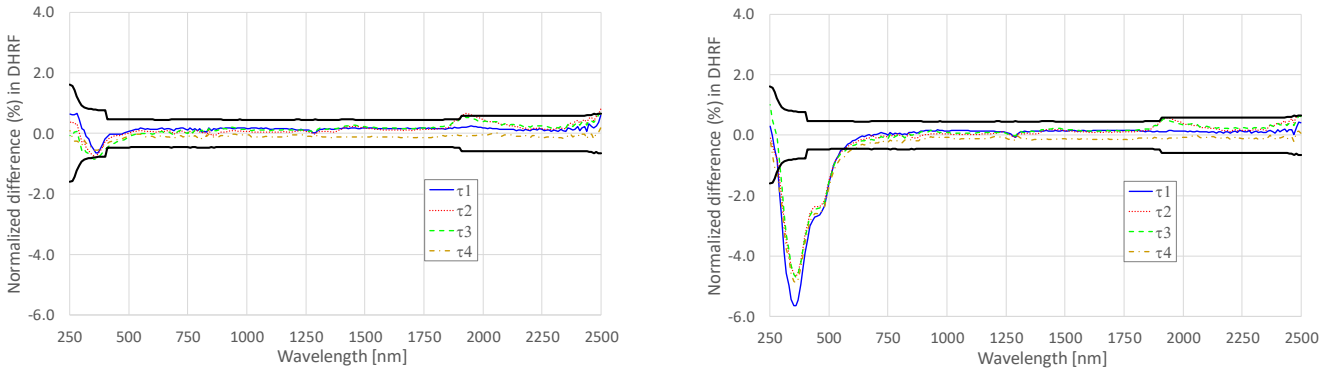


Figure 3. Normalized difference (%) in DHRF for control (left) and UV exposed (right) ceramic samples as a function of wavelength at each characterization time during the exposure period.